

# BIOMORPHIC EXPLORERS

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DARPA WORKSHOP on Biologically Inspired Approaches for MAV's  
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BIOMORPHIC EXPLORERS

BIOMORPHIC EXPLORERS

- SMALL, DEDICATED, LOW-COST EXPLORERS THAT CAPTURE SOME OF THE KEY FEATURES OF BIOLOGICAL EXPLORERS
- CONDUCTED WORKSHOP, AUG 19-20, 1998
  - SPONSORED BY NASA/JPL
  - VERY SUCCESSFUL; OVER 150 PARTICIPANTS

## BIOMORPHIC EXPLORERS

### OPENING REMARKS FIRST NASA/JPL WORKSHOP ON BIOMORPHIC EXPLORERS FOR FUTURE MISSIONS

Dr. Peter B. Ulrich

- “The fiscal and physics constraints we face will, in Darwinian fashion, lead us to do what nature does so well...economize and minimize. Emerging from that vision, the Biomorphic Explorer will be an economic and minimalist marvel that captures the best that nature has to offer”

## BIOMORPHIC EXPLORERS

# Biomorphic Explorers: Classification (Based on Mobility and Ambient Environment)

## Biomorphic Explorers

Aerial

Biomorphic Surface Systems

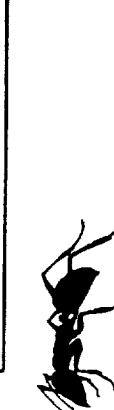
Biomorphic Subsurface Systems



Honey Bee



Ant



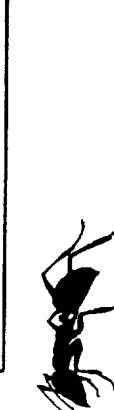
Soaring Bird



Humming Bird



Jelly Fish



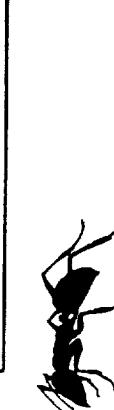
Centipede



Snake



Earthworm



Germinating Seed



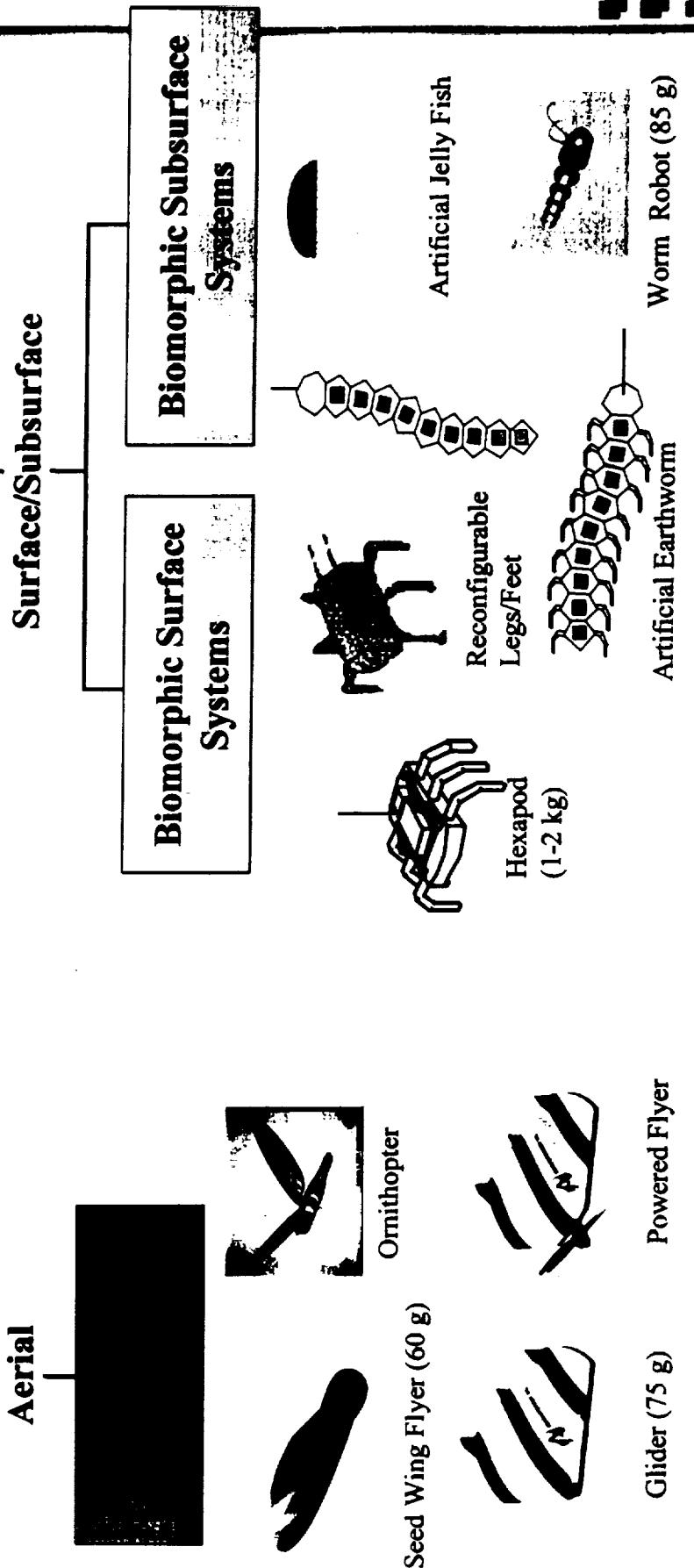
Germinating Seed

Examples of biological systems that serve as inspiration for designing the biomorphic explorers in each class

## BIOMORPHIC EXPLORERS

# Biomorphic Explorers: Classification (Based on Mobility and Ambient Environment)

## Biomorphic Explorers



**Candidate biomorphic explorers on the drawing board, with mass of design under study in 1998 in parentheses**

## BIOMORPHIC EXPLORERS

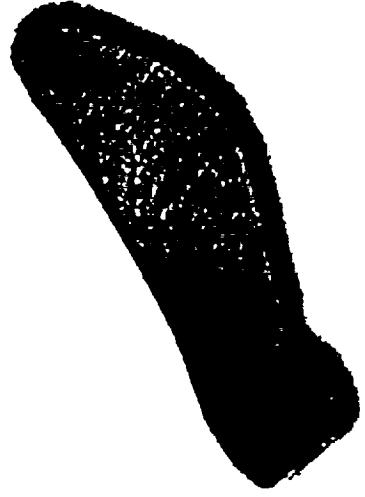
## BIOMORPHIC EXPLORERS

- KEY FEATURES
  - VERSATILE MOBILITY: aerial, surface, subsurface, and in fluids
  - ADAPTIVE, DISTRIBUTED OPERATION
- BIOMORPHIC COMMUNICATIONS
- BIOMORPHIC SENSOR FUSION
- BIOMORPHIC COOPERATIVE BEHAVIOR

# Biomorphic Flight Systems: Vision

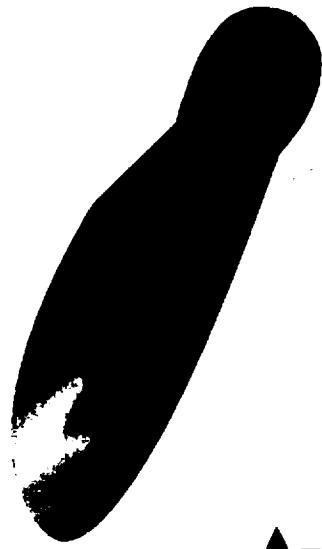
- Extended reach over all kinds of terrain
- Unique perspective for imaging and Spectral Signature
- Many flyers work in cooperation with larger aircraft, and balloons to enable new missions to reach currently inaccessible locations

## BIOMORPHIC FLIGHT SYSTEMS



TOTAL MASS: 57 g →  
PAYLOAD MASS: 48 g

a. Seed Wing Pod



b. Seed Wing Pod Flyer



TOTAL MASS: 57 g  
← PAYLOAD MASS: 32 g

c. Biomimetic Glider

Biomimetic flight systems offer rapid mobility and extended reach. For comparison the above illustrates for the same total mass of the system, the respective payload fractions in each case



TOTAL MASS: 57 g →  
PAYLOAD MASS: 6 g

d. Biomimetic Flyer

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## BIOMORPHIC EXPLORERS

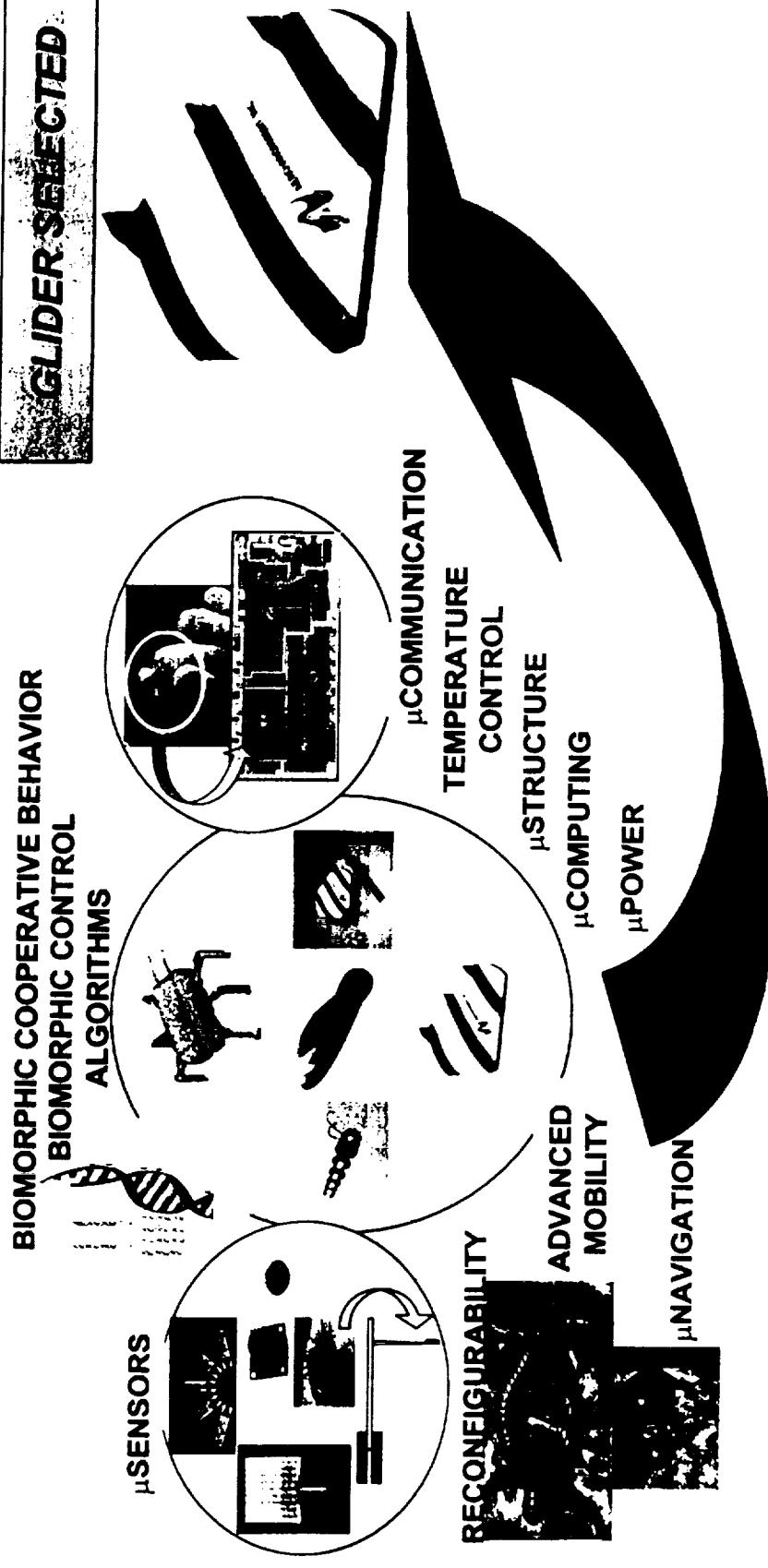
## BIOMORPHIC EXPLORERS

### PAYOFF

- BIOMORPHIC EXPLORERS, IN COOPERATION WITH CURRENT EXPLORATION PLATFORMS CAN ENABLE
  - EXPLORATION OF CURRENTLY INACCESSIBLE AND/OR HAZARDOUS LOCATIONS
  - MUCH BROADER COVERAGE OF EXPLORATION SITES
  - EXPLORATION AT LOWER COST

## BIOMORPHIC EXPLORERS

# Biomorphic Explorer: Conceptual Design



## GLIDER BASELINE DESIGN CHARACTERISTICS

- MASS: 75 g
- PAYLOAD FRACTION: 60 %
- GLIDE RATIO, L/D ~ 5.8
- LARGE RANGE OF AERIAL MOBILITY:  
~ 50 km to 100 km
- LEVERAGE FROM NAV TECHNOLOGY
- VOLUME: 300 cm<sup>3</sup>
- ACTIVE FLIGHT CONTROL
- SOLAR NAVIGATION
- SOARING FLIGHT IN RISING CURRENTS
- COOPERATIVE MISSION: 32 GLIDERS
- COVERAGE AREA: ~ 100 km x 100 km

## SELECTION CRITERIA

- LOW MASS/VOLUME
- HIGH PAYLOAD FRACTION
- LARGE RANGE OF MOBILITY
- ACTIVE CONTROL
- IMPLEMENTATION READINESS

# Biomorphic Gliders

- Small, simple, low-cost system ideal for distributed measurements, reconnaissance and wide-area dispersion of sensors and small experiments.
- Payload mass fraction 50% or higher.

- small mass (100 g - 500 g)
- low radar cross section
- larger numbers for given payload due to low mass
- amenable to cooperative behaviors
- missions use potential energy: deploy from existing craft at high altitude
- Captures features of soaring birds, utilizing rising currents in the environment
- *Adaptive Behavior*
- *Self Repair features*



# Biomorphic Gliders

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- Payload mass fraction 50% or higher.

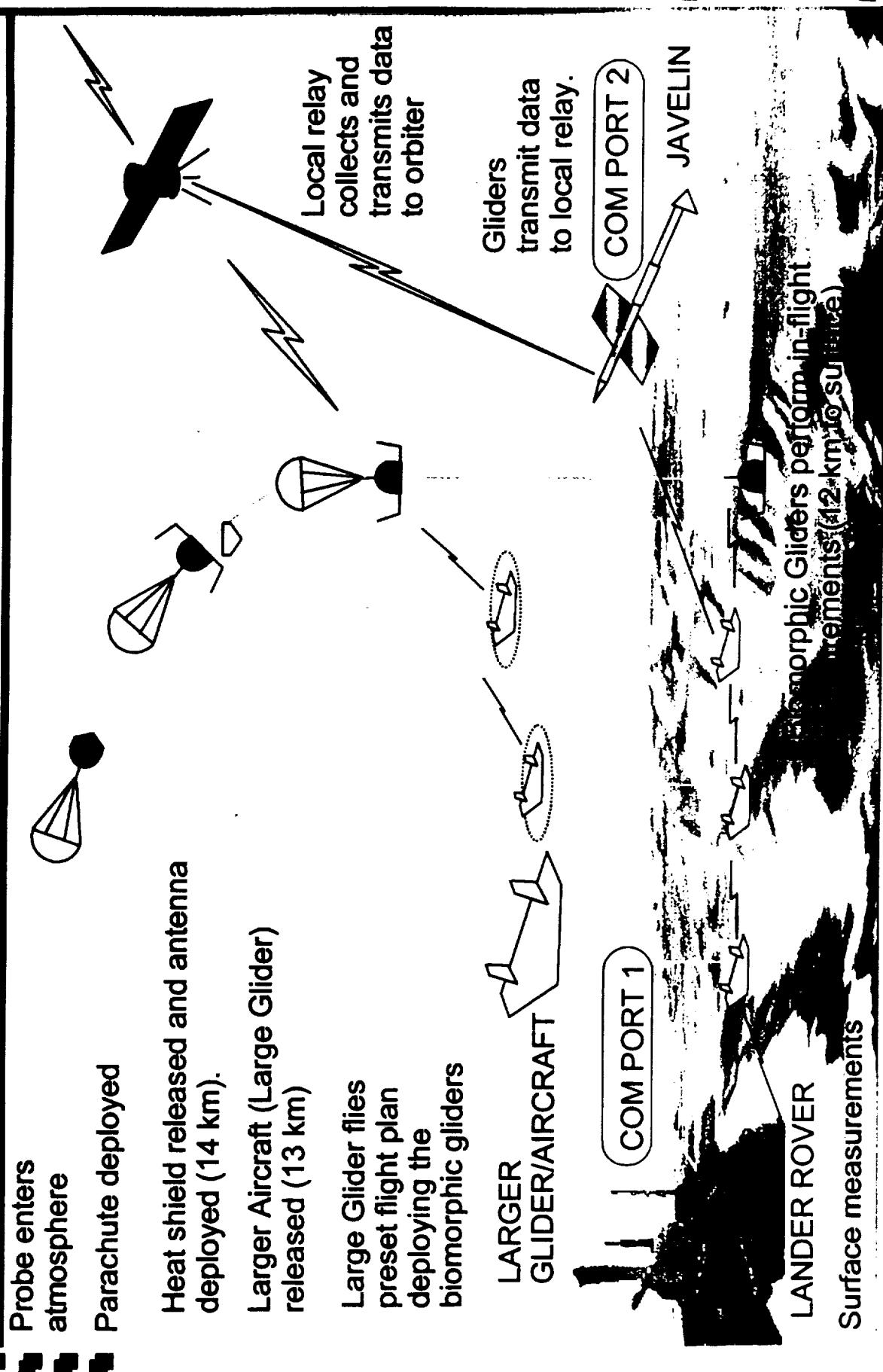


|                | Baseline |
|----------------|----------|
| Total Mass (M) | = 57     |
| Payload (P)    | = 32     |
| P/M fraction   | = 56     |
| Wing Span      | = 0.19   |
| Wing Area      | = 0.014  |
| Volume         | = 168    |
| Flight Speed   | = 90     |
| Range          | = 50     |
| Duration       | = 590    |
| Glide Ratio    | = 5.3    |
| Starting Alt.  | = 10     |
|                |          |
|                | 75       |
|                | 45       |
|                | 60       |
|                | 0.25     |
|                | 0.021    |
|                | 300      |
|                | 90       |
|                | 55       |
|                | 650      |
|                | 5.8      |
|                | 10       |
|                | 250      |
|                | 150      |
|                | 60       |
|                | 0.50     |
|                | 0.071    |
|                | 1700     |
|                | 90       |
|                | 72       |
|                | 800      |
|                | 7.5      |
|                | 10       |
|                | 5200     |
|                | 90       |
|                | 83       |
|                | 1300     |
|                | 8.6      |
|                | 10       |
|                | 10 km    |

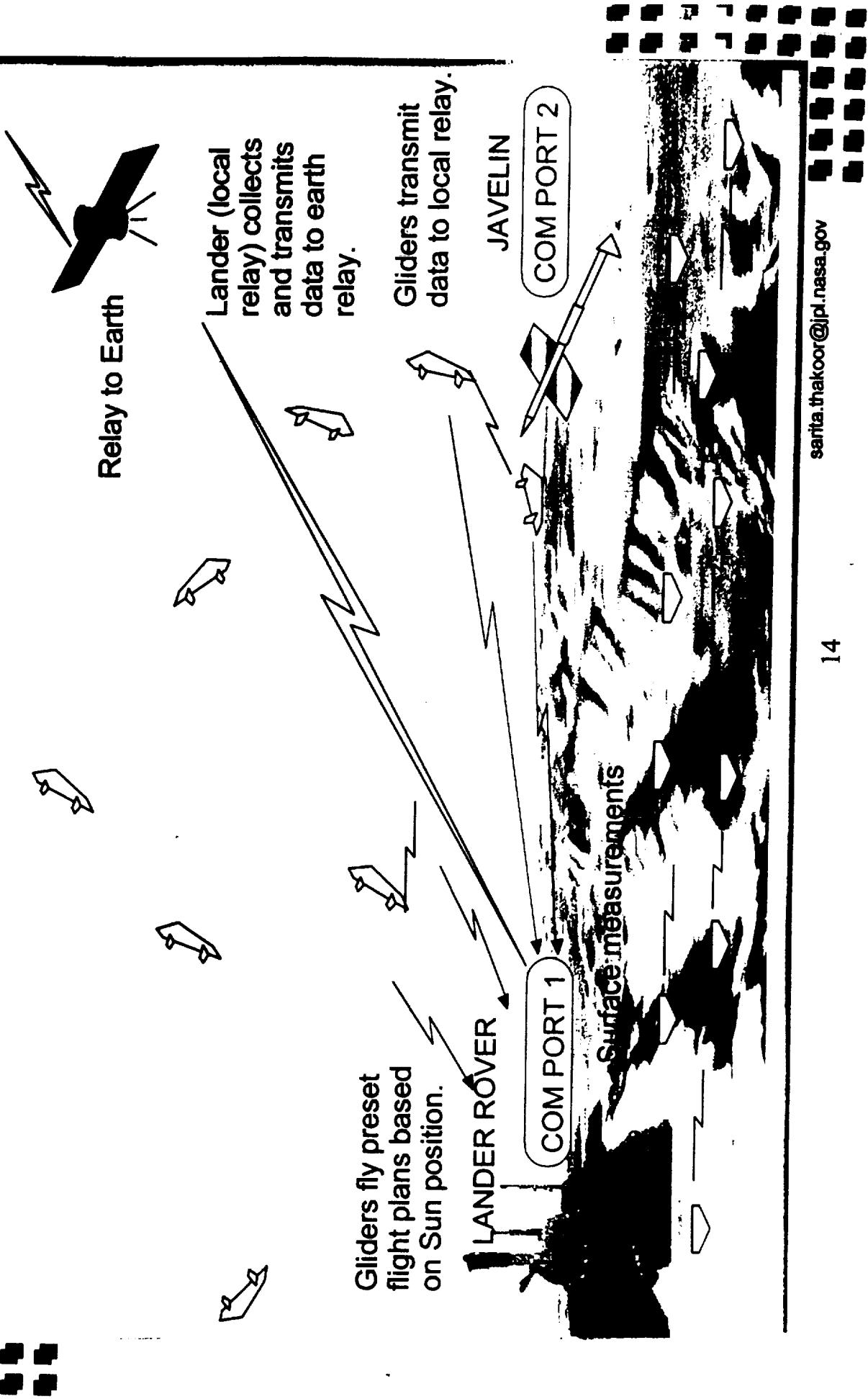
• Performance calculations based on conditions at 5 km altitude on Mars for a glider that has an analog 2gm camera

• Volume based on projected area x mean thickness x 1.2

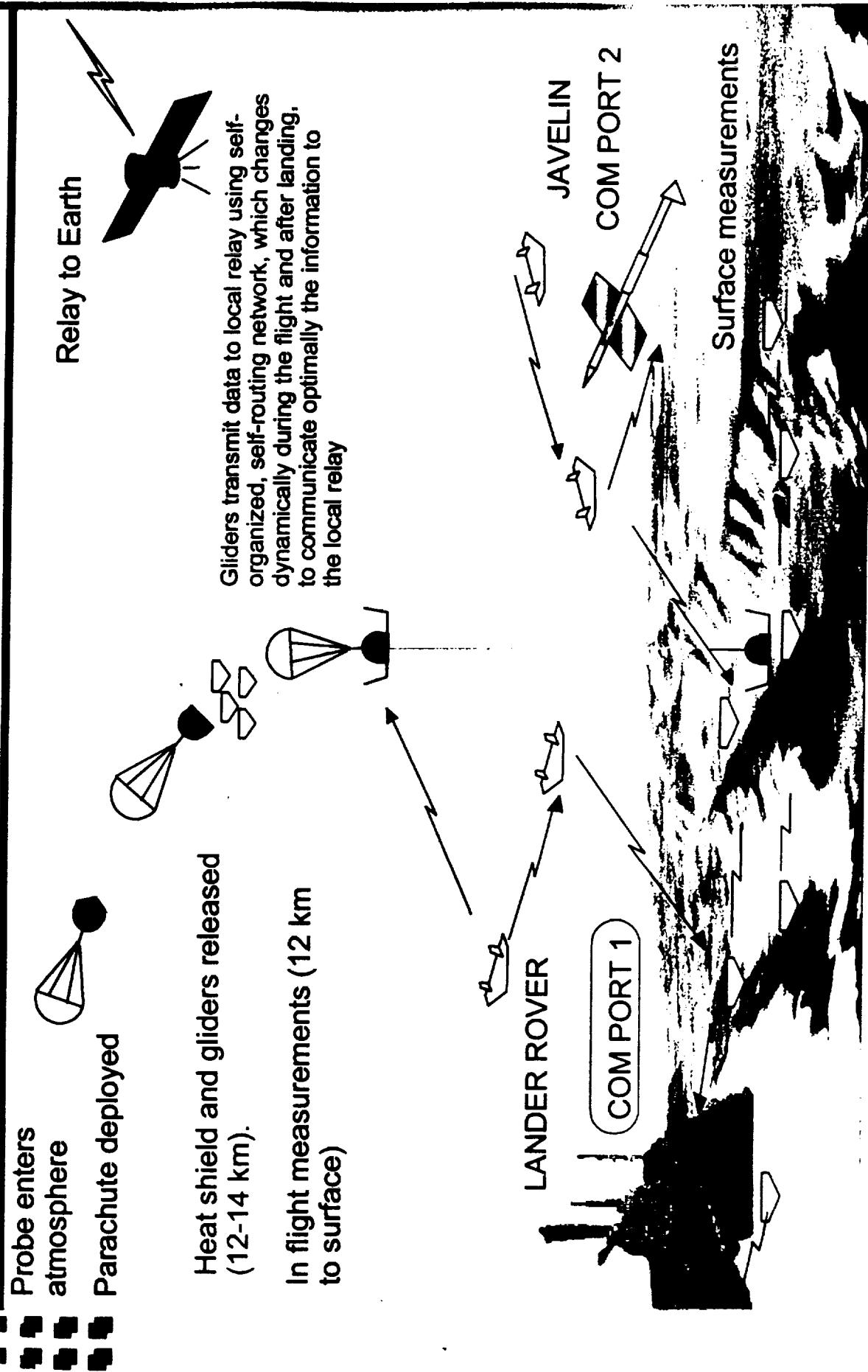
## Biomorphic Glider Deployment Concept: Larger Glider Deploy/Local Relay

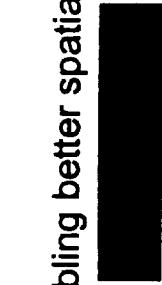


## Biomorphic Glider Deployment Concept: Probe Deploy/Lander Relay



## Biomorphic Glider Deployment/Telecommunication Concept

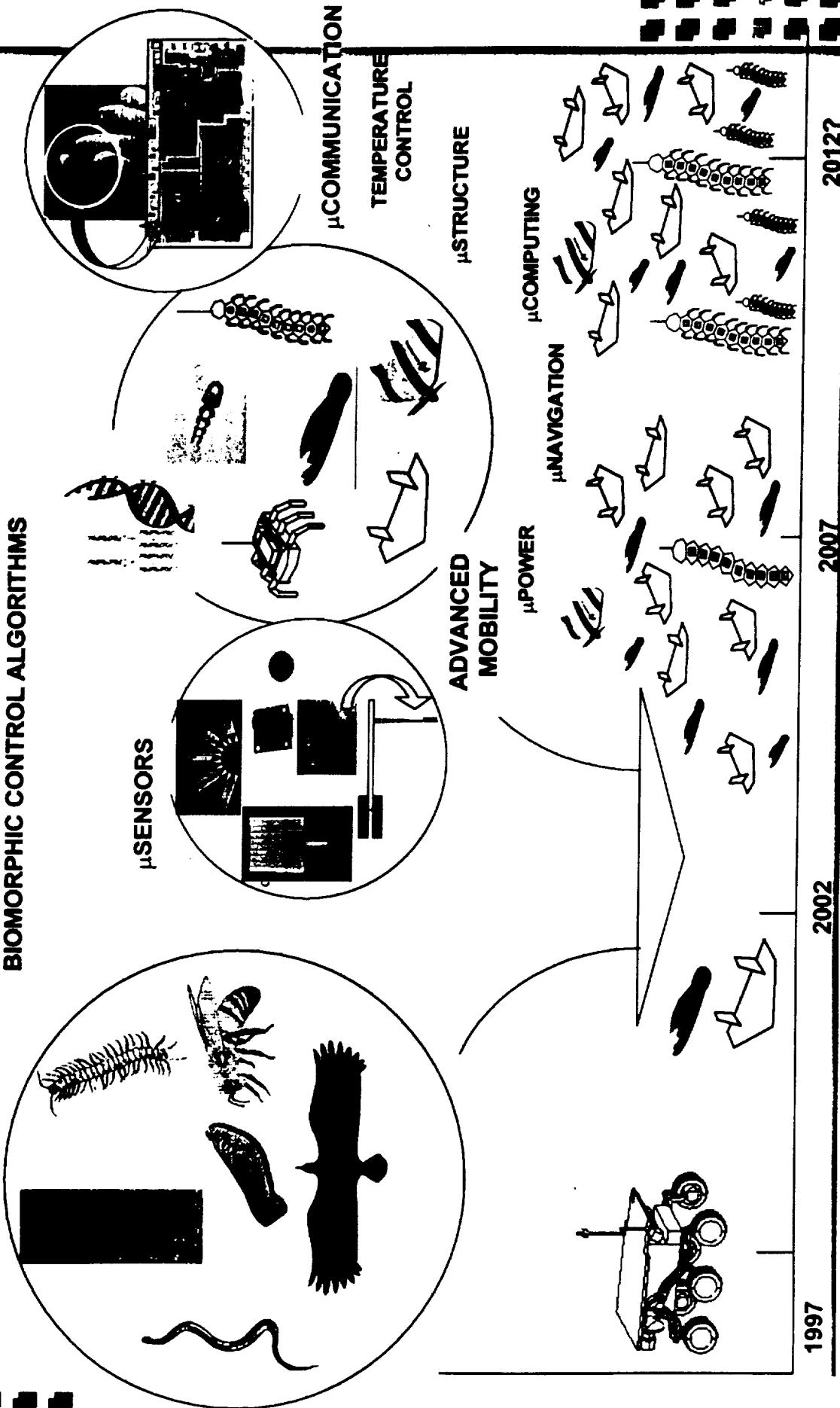




**Enabling better spatial coverage and access to hard-to-reach and hazardous areas at low recurring cost**

SUMMARY & ROADMAP

**BIOMORPHIC COOPERATIVE BEHAVIOR  
BIOMORPHIC CONTROL ALGORITHMS**



## BIOMORPHIC EXPLORERS

# COORDINATED/COOPERATIVE EXPLORATION SCENARIO

### BIOMORPHIC FLYERS

- ATMOSPHERIC INFO GATHERING:
- DISTRIBUTED MULTIPLE SITE MEASUREMENTS
- CLOSE-UP IMAGING, EXOBIOLOGY SITE SELECTION
- DEPLOY PAYLOAD: INSTRUMENTS/CRAWLERS
- SAMPLE RETURN RECONNAISSANCE



COOPERATIVE ORGANIZATION OF LANDER, ROVER, AND A VARIETY OF INEXPENSIVE BIOMORPHIC EXPLORERS WOULD ALLOW COMPREHENSIVE EXPLORATION AT LOWER COST WITH BROADER COVERAGE.

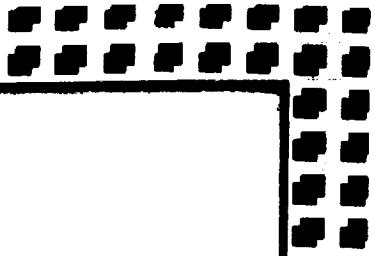
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# Applications

BIOMORPHIC EXPLORERS

- **Distributed Aerial Measurements**
  - Ephemeral Phenomena
  - Extended Duration using Soaring
- **Delivery and lateral distribution of Agents (sensors, surface/subsurface crawlers, clean-up agents**
- **Close-up Imaging, Site Selection**
- **Meteorological Events: storm watch**
  - Reconnaissance
- **Biological Chemical Warfare**
  - Search and Rescue etc
  - Surveillance
  - Jamming



## ACKNOWLEDGMENTS

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